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VOLUME

**NASA CR-152569**

CONTRACT NO. NAS8-31690  
27615-6007-RU-04  
DR-SE-03A

**4**

# SPECIFICATIONS

## BOOK 1

### LABCRAFT PAYLOAD GENERAL SPECIFICATION

(NASA-CR-152569) ATMOSPHERE, MAGNETOSPHERE  
AND PLASMAS IN SPACE (AMPS). SPACELAB  
PAYLOAD DEFINITION STUDY. VOLUME 4, BOOK 1:  
LABCRAFT PAYLOAD GENERAL SPECIFICATION  
Final Report (IBW Defense and Space Systems G3/12

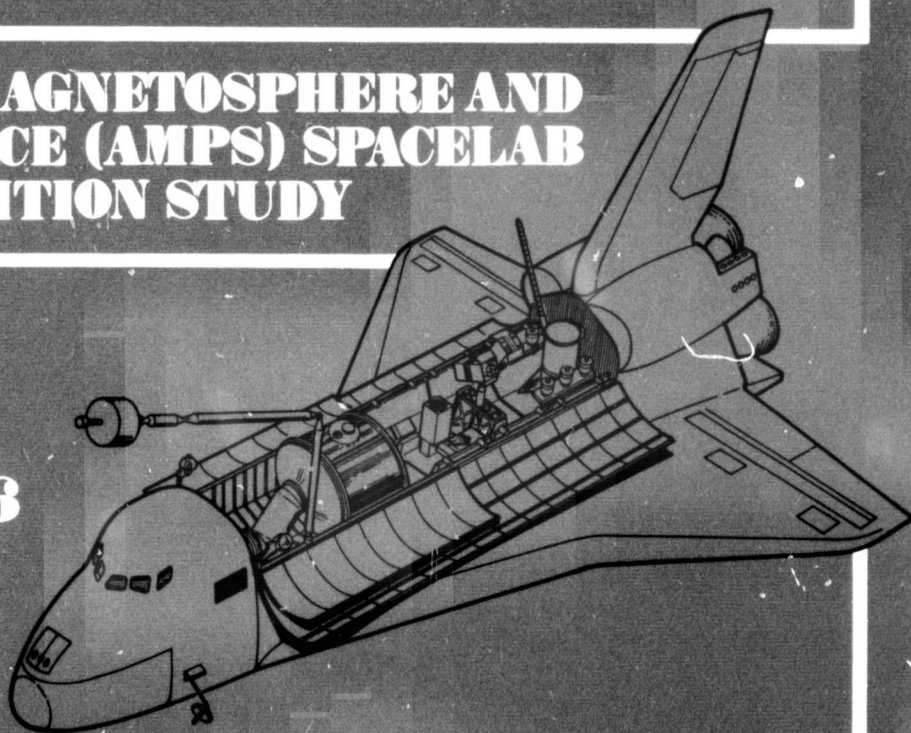
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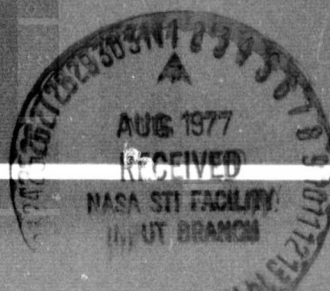
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## ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS) SPACELAB PAYLOAD DEFINITION STUDY

**Final Report  
November 1976**



Prepared for  
National Aeronautics  
and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland 20771



**TRW**  
DEFENSE AND SPACE SYSTEMS GROUP

ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS)  
SPACELAB PAYLOAD DEFINITION STUDY  
FINAL REPORT

VOLUME IV  
BOOK 1 - LABCRAFT PAYLOAD GENERAL SPECIFICATION

Document No.  
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Approved by:

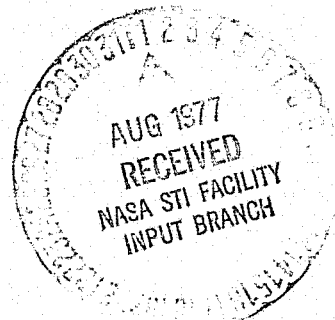


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## 1. SCOPE

This document specifies the performance, design, verification and operational requirements for Labcraft equipment and Labcraft integrated payloads. The requirements, stated herein, are based on the current definition of Spacelab and Space Transportation System equipment and the constraints associated with their use. This document will be revised to reflect modifications as necessary. See 6.1 for definitions of terms.

## 2. APPLICABLE DOCUMENTS

### 2.1 OVERRIDING DOCUMENT. The requirements stated in this document are derived from:

GSFC (TBD) Labcraft Program Specification

It is overriding in case of disagreement, except where specific waivers have been granted.

### 2.2 REFERENCE DOCUMENTS. The following documents of latest issue form a part of this specification to the extent specified herein.

#### 2.2.1 Program level documents.

- (a) ESTEC/MSFC SLP-2100 Spacelab Systems Requirements Document
- (b) ESTEC/MSFC SLP-2104 Spacelab Payload Accommodation Handbook
- (c) JSC-07700, Vol. XIV Space Shuttle System Payload Accommodations (Level II), Program Definition and Requirements

#### 2.2.2 Labcraft system requirements.

- (a) NASA-NHB-XX Safety Policy and Requirements for Payloads Using the National Space Transportation System
- (b) JSC-11123 Space Transportation System Payload Safety Guidelines Handbook
- (c) KSC-K-SM-14 Launch Site Accommodations Handbook for STS Payloads
- (d) MIL-E-5272C  
Sept. 1970 Environmental Testing, Aeronautical and Associated Equipment, General Specification for
- (e) JSC-08060 Space Shuttle System Pyrotechnic Specification

- (f) NSS HP1740.1 NASA Aerospace Pressure Vessel Safety Standard
- (g) SL-E-0001 Specification Electromagnetic Compatibility Requirements, Systems for the Space Shuttle Program.

2.2.3 Mission assurance.

- (a) FED-STD-209 Clean Room and Work Station Requirements, Controlled Environment
- (b) MIL-STD-889 Sept. 1969 Dissimilar Metals
- (c) NASA Document 10M33107 Design Guidelines for Controlling Stress Corrosion Cracking
- (d) NASA SP-8040 Failure Control, Metallic Pressure Vessels
- (e) MSFC-PROC-404 Gases, Drying and Preservation, Cleanliness Level and Inspection Methods
- (f) MIL-STD-810 Environmental Test Methods
- (g) MIL-STD-454 Standard General Requirements for Electronic Equipment
- (h) NHB 5300.4(1C) Inspection System Provisions for Aeronautics and Space Systems Materials Components and Services

### 3. REQUIREMENTS

#### 3.1 LABCRAFT SYSTEM. This paragraph establishes certain general design, performance, and interface requirements for Labcraft hardware and software.

3.1.1 System definition. The Labcraft System is an assembly of hardware and software designed to satisfy the mission objectives of the Labcraft program. It includes both flight and ground components.

3.1.1.1 The Labcraft Payload may include any of the following generic classes of components:

- (a) Spacelab elements (e.g., Spacelab equipment assigned or bailed to the Labcraft program)
- (b) Labcraft instruments
- (c) Labcraft flight support equipment
- (d) Labcraft flight software
- (e) Multi-mission support equipment.

3.1.1.2 The ground elements of the Labcraft System will consist of ground support equipment (GSE), training equipment, and other specialized items required to support flight operations such as equipment and/or software required by the payload operations control center (POCC).

3.1.1.3 Labcraft payload. Labcraft payloads may be configured to fly in any of the standard Spacelab configurations defined in Reference 2.2.1(b) (module only, pallet only, or module plus pallet) or in approved variations of the above Spacelab arrangements. Labcraft payloads may be configured to occupy all of the Orbiter payload capability (dedicated flights) or only part of the Orbiter payload capacity (shared flights).

3.1.1.4 Space Shuttle flight system. The space Shuttle flight system carries the Labcraft payload to orbit and provides basic support services (electrical power, pointing and stabilization, orbit maintenance, crew life support, thermal control, stowage, payload manipulation/stowage, ascent/descent protection, primary structural support) to all payload components. It consists of the Orbiter vehicle, Spacelab, an external tank, and two solid rocket boosters. The Orbiter vehicle carries the payload (Spacelab) in its cargo bay, and returns the payload to earth at the completion of the mission. Additional details on the Shuttle capabilities and the Orbiter-payload interfaces may be found in Reference 2.2.1(c).



3.1.1.5 System operating cycle. Labcraft payloads will be designed for reuse (see 3.9.2.1). The typical operational sequence will involve one of the following scenarios following the nominal seven day on-orbit mission:

- (a) Repair, refurbishment, reflight
- (b) Repair, reconfiguration, reflight
- (c) Either of the above plus an extended storage period prior to reflight.

Payloads may also remain on-orbit up to 30 days followed by any of the above sequences.

3.1.1.6 Coordinate systems. Labcraft payloads shall use as a primary reference the coordinate system defined in 2.1.3 of Reference 2.1.1(b). Additional coordinate systems such as the Orbiter body axes defined in 2.1.2 of Reference 2.1.1(b) may be used where appropriate or more convenient. Special coordinate systems (e.g., the instrument package orientation at the end of a deployed mast) may also be required to satisfy Labcraft requirements.

3.1.2 General design requirements. The following requirements apply to all hardware and software to be developed under this specification.

3.1.2.1 Low cost. Labcraft equipment shall reflect low cost approaches derived from the unique characteristics of the Shuttle vehicle. In particular, the following factors shall be considered in the design and/or selection of Labcraft hardware:

- (a) Use of off-the-shelf hardware
- (b) Use of the shuttle weight, space, and power capability to avoid design complexity (e.g., miniaturization)
- (c) Maximum usage of existing Spacelab and Orbiter support capabilities
- (d) Maximum usage of the Orbiter crew
- (e) Short duration mission with opportunity for repair and refurbishment prior to reflight.

3.1.2.2 Cleanliness. Labcraft support equipment shall be designed so that it does not contribute to contamination of the Orbiter or Spacelab environment beyond that which is

permissible due to outgassing or as allowed per 3.9.4 below. Further, the equipment shall be capable of being cleaned of contaminants (e.g., particulate matter, salt deposits, moisture) following reentry.

- 3.1.2.3 Modularity. Where feasible, modularization shall be included in equipment design to facilitate growth and equipment repair/refurbishment. Incorporation of modularity shall be based on a judicious tradeoff between potential benefits and equipment cost.
- 3.1.2.4 Crew interfaces. Labcraft equipment design shall include consideration of features to optimize the efficiency and safety of the Spacelab crew. This includes the command and control functions plus peripheral crew activities such as repair, reloading, and stowage. For pallet-mounted equipment, the possibility of emergency extra-vehicular activity (EVA) shall be reflected in Labcraft support equipment design.
- 3.1.2.5 Safety. Protection of the flight and ground crew from uncontrolled hazards shall be a primary feature of all Labcraft equipment designs. Specific safety requirements are contained in 3.9.5 below.
- 3.1.2.6 Access. Labcraft payload designs shall include consideration of access requirements which might arise during payload assembly, pre-launch checkout, on-orbit repair, or during post-flight refurbishment, disassembly, or reconfiguration.
- 3.1.3 Payload performance. Labcraft payloads shall be designed to perform a variety of classes of experiments including but not limited to:
  - (a) Passive measurements via remote sensing of the atmosphere and magnetosphere
  - (b) In-situ measurements in the vicinity of the Orbiter and/or the subsatellite
  - (c) Active (cooperative) measurements of the atmosphere and magnetosphere
  - (d) Transient modification of the atmosphere
  - (e) Observations of terrestrial and oceanic phenomena
  - (f) Solar, planetary and stellar observations.
- 3.1.3.1 Allowable orbits. Labcraft payloads shall be designed to operate at orbital altitudes from TBD to TBD km and orbital inclinations from TBD to TBD degrees.

3.2 LABCRAFT SUPPORT EQUIPMENT. Labcraft support equipment may be designed to satisfy one or more of the following objectives:

- (a) Provide interfacing equipment between various payload elements such as instrument-Spacelab or payload-Orbiter
- (b) Provide required instrument support functions such as sensor pointing, energy storage, sensor deployment, data processing, subsatellites
- (c) Provide direct support to the conduct of experiments such as the release of chemical substances or the positioning of a test body.

In addition to the above hardware, Labcraft payloads may also include Labcraft-peculiar flight software.

3.2.1 Performance requirements. Labcraft support equipment will be designed to satisfy one or more of the following performance objectives.

3.2.1.1 Sensor pointing. A method for accurately pointing selected Labcraft instruments within the (3 sigma) tolerances shown in Figure 3-1 shall be provided.

POINTING AXIS	PERFORMANCE PARAMETER	POINTING ACCURACY (ARC-SEC)	POINTING STABILITY (ARC/20 SEC)	STABILITY RATE (ARC-SEC/SEC)	ATTITUDE DETERMINATION (DEGREE)
	LINE-OF-SIGHT (LOS) ROLL	TBD	TBD	TBD	TBD

Figure 3-1. Pointing System Performance

This pointing capability shall be provided for payloads up to TBD meters in diameter and TBD meters long and weighing from TBD to TBD kilograms. Operation of the sensor pointing system may be autonomous or it may include pointing or attitude information from external sources such as the Orbiter G&NS or the Labcraft instrument.

3.2.1.2 Remote placement. A (boom) structure shall be provided to place instruments or test bodies in locations which are remote from the Orbiter/Spacelab environment. The boom structure shall be pallet-mounted, shall accommodate

up to TBD kilograms of payload, and shall extend up to TBD meters from the stowed position. The boom structure must be capable of positioning its payload within meters of the desired position and shall establish the orientation of the instrument payload to within TBD degrees in any of three orthogonal axes, and maintaining such position and stability for extended periods of time.

3.2.1.3 Releases. Labcraft experiments may require the release and injection of various chemicals into the atmosphere. These chemicals will be released from the pallet in a container or canister, allowed to physically separate from the Orbiter, and finally injected into the atmosphere.

3.2.1.4 Subsatellites. A deployable subsatellite shall be provided to carry instruments to locations which are beyond the capability of the boom structure specified in 3.2.1.2 above. It shall provide all necessary support to the instrument payload (power, thermal control, data processing, etc.) and shall include a communication link capable of providing satisfactory command and data transmission between the satellite and the Orbiter. The subsatellite link must be capable of transmitting data rates up to TBD kilometers from the Orbiter when interfacing with the Orbiter-provided payload interrogator system. Two types of subsatellites shall be provided — a recoverable type and a low cost, non-recoverable type. Subsatellite deployment may be accomplished via the RMS or by use of a dedicated launcher. The RMS will be used for all subsatellite retrieval.

3.2.1.5 Data processing. Labcraft support equipment shall be provided to supplement the existing Spacelab command and Data Management Subsystem (CDMS). This will include the following capabilities:

- (a) Payload control and display capability for both Spacelab module and OAFD control stations as required by the payload configuration
- (b) Dedicated control and display hardware. This includes minicomputers or microprocessors for instrument control
- (c) Supplemental analog data recorder
- (d) High rate (up to 6.4 mpbs) digital data multiplexer (if not provided by Spacelab).

3.2.1.6 Thermal control. Thermal control components shall be provided to augment the Spacelab thermal control subsystem. This may involve simple devices such as multi-layer insulation or electrical heater or it may require a more extensive set of hardware. The final determination of requirements shall be based on an analysis of the payload configuration proposed for flight.

3.2.1.7 Structural support. Mounting platforms, adapters, and support structure shall be provided as required to accommodate Labcraft instruments or the entire payload. Special structure elements such as caging devices, hold-downs, and releases will be provided to satisfy operational or safety requirements.

3.3 PALLET-MOUNTED EQUIPMENT. This paragraph defines requirements for all Labcraft payload equipment intended for pallet mounting.

3.3.1 Physical requirements. This paragraph describes the general physical requirements and constraints imposed on pallet-mounted equipment.

3.3.1.1 Structural attachment. Equipment may be mounted on the Spacelab pallet in one of the following ways:

- (a) Directly to pallet hardpoints
- (b) To hardpoints via bridging secondary structure
- (c) On the pallet panels
- (d) On pallet cold plates
- (e) Indirectly via other equipment
- (f) Bridging between two pallet segments.

3.3.1.1.1 All mounting methods must comply with the structural limitations on the pallet as defined in 4.1.3 of Reference 2.2.1(b). In addition, all attachment methods shall be designed to survive the crash loads specified in 5.2 of Reference 2.2.1(b). The factor of safety used in the design shall be conservative so as to reduce the testing requirements and, correspondingly, the total cost of a qualified flight structure. The required factors of safety are:

- (a) Yield load = 2.0 by limit load and ultimate load = 3.0 by limit load.

3.3.1.1.2 Equipment mounting in a way which bridges between pallet segments is a special case requiring careful analysis and prior approval before it can be proposed.

- 3.3.1.2 Stowed volume. The stowed volume and maximum dimensions of pallet-mounted equipment are limited by the pallet structure and by the Orbiter cargo bay envelope as defined in 4.1.3 of Reference 2.2.1(b). Additional constraints may be imposed by other elements of the total payload.
- 3.3.1.3 Deployed equipment. Pallet-mounted equipment may be deployed beyond the cargo bay envelope if such deployment is controlled to prevent contact with the Orbiter structure. Equipment exceeding the cargo bay envelope must have a capability for emergency ejection and/or retraction. Stowage of deployed equipment and satisfactory attachment to the pallet structure is required prior to reentry (same requirements as stated in 3.3.1.1 above). Deployment may employ a dedicated built-in mechanism or may use the Orbiter RMS. Other restrictions on deployable devices may result from consideration of the total payload design. Actuation and control of all deployment mechanisms shall be located on the Orbiter aft flight deck. Initiation of deployment and retraction shall be by manual commands. Retraction and deployment sequences may be manually controlled or automated. Redundant controls for deployment devices may be located in the Spacelab module.
- 3.3.1.4 Environments. Pallet mounted equipment is exposed to the natural environment of space (vacuum, radiation, etc.) generally defined in Reference 2.2.1(c) and to the Shuttle ascent/descent environment described in 5.2 of Reference 2.2.1(b).
- 3.3.1.5 Alignment. All alignment required by the Labcraft payload shall be provided by the payload equipment. The Orbiter/ Spacelab does not have any capability for providing a reference for physical alignment. (However, the Orbiter GN&C can provide Orbiter or a target state vector data in a variety of coordinate systems). Alignment errors between the Orbiter IMU and the payload are expected to be at least two degrees.
- 3.3.2 Electrical requirements. Labcraft payload equipment mounted on pallets shall comply with the following requirements and constraints.
- 3.3.2.1 Electrical power. Electrical power for pallet equipment is available from three separate busses:
- (1) A 28-volt DC essential power bus (limited to 25 watts total for any given payload)
  - (2) A normal 28-volt DC bus
  - (3) A three-phase 115/200 volt 400 Hz AC bus.

All payload power is distributed via distribution boxes (one per pallet) provided by the pallet and mounted on the pallet sill. No electrical power is available on the pallet during ascent or descent. Additional details on power quality and on total mission energy available to payloads may be found in 4.2 of Reference 2.2.1(b). Power control to any Labcraft payload equipment may be accomplished from the OAFD (all payload power), from the OAFD or the pressurized module via the Spacelab CDMS to switches in the power distribution box or to switches in individual payload equipment.

- 3.3.2.2 Electrical signals. Signals to or from Labcraft equipment may be routed by direct wire or coax cable to the Spacelab or to the Orbiter via Spacelab or they may be routed via the pallet-mounted RAU. The RAU capabilities are defined in 4.4.2 of Reference 2.2.1(b). All pallet equipment shall include telemetry output signals which will indicate the state-of-health of the item as well as its operating mode.
- 3.3.2.3 Ground and shielding. Labcraft equipment shall follow the ground and shielding procedures as defined in Reference TBD.
- 3.3.2.4 Interconnecting cabling. All interconnecting cabling to or between payload equipment must be provided as part of the payload. All direct wiring or coaxial cabling from the payload to Spacelab or Orbiter must also be provided. All cabling installations must include tiedowns and thermal protection. Cables which interface with existing Spacelab equipment must incorporate compatible connectors as defined in Reference 2.2.1(b).
- 3.3.3 Field of view. Labcraft equipment or instruments requiring a clear field-of-view or operating envelope must be located on the pallet with due regard to obstructions from the Spacelab, the Orbiter vehicle and other Labcraft payload elements. Early identification of such requirements is mandatory to insure that they are met.
- 3.3.4 Thermal control. Payload thermal control requirements must be compatible with the capabilities of the Spacelab and with the required Orbiter orientation. The primary method of heat dissipation shall be through the Spacelab/Orbiter cooling loop and/or by direct radiation to space. Maximum use shall be made of Spacelab/Orbiter provided thermal control resources. Equipment must be designed to minimize unwanted transfer of heat to adjacent payload elements and to Spacelab pallet structure. System analysis shall be performed and thermal insulation designed to minimize thermal transients and accomplish acceptable temperature

variations within the Labcraft and payload equipment. Active thermal control elements (e.g., heaters) may be employed and their power dissipation shall be part of the equipment power budget.

- 3.3.5 Electromagnetic compatibility. All Labcraft equipment shall be compatible with the requirements of Reference 2.2.2(g).
- 3.3.6 Electric and magnetic fields. The design of Labcraft payload equipment shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produce by the specific payload unit, by other payload components, or by the Spacelab/Orbiter vehicle. Further, Labcraft equipment shall not create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.
- 3.3.7 Testing. Ground testing of Labcraft pallet-mounted equipment shall be accomplished via the pallet flight cabling and preferably via the Spacelab CDMS/RAU installed on the pallet. There shall be no direct cable tie from GSE to the pallet once the payload is installed in the Orbiter, except that such connections may be permissible to accomplish post-flight instrument calibration. On-orbit testing of Labcraft equipment must be provided as part of the payload design and use of the Spacelab CDMS to accomplish such testing is encouraged. On-orbit testing shall be limited to calibration and function verification and shall not include fault isolation to LRU level.
  - 3.3.7.1 Ground support equipment (GSE). Pallet-mounted equipment design shall include provisions for interfacing with appropriate mechanical and electrical GSE required to support integration, ground transportation, and pre-launch operations.
- 3.3.8 Operational requirements. This paragraph describes the operational requirements which must be satisfied by Labcraft pallets and pallet-mounted equipment. Operational requirements include both ground and flight activities.
  - 3.3.8.1 Control. All pallet equipment shall be designed for remote control. Manual operations are possible via the Orbiter RMS when necessary and emergency operations involving EVA are also feasible for hazard avoidance or hazard reduction. All payload configurations shall incorporate a capability for control of experiment apparatus from a ground-based payload operations control center (POCC). Data transmission between the payload and the POCC shall be via the Orbiter communications system.



3.3.8.2 Integration. Pallet-mounted equipment and integrated pallet segments shall be designed to meet the constraints imposed by the proposed Spacelab payloads integration process. Among these constraints are the following:

- (a) Limited schedule (may be as short as TBD days) for all launch site integration (levels III/II and I)
- (b) Limited access following level I integration
- (c) Class 100,000 cleanliness shall be maintained during all integration activities. Where this cleanliness level is not adequate, the individual instrument must provide its own environmental cover
- (d) Level IV integration may not occur at the launch site; hence the pallet equipment design must consider a transportation environment
- (e) Payload equipment is installed in a horizontal Orbiter and erected vertically prior to launch; vertical payload removal may be required using vertical access equipment.

3.4 MODULE-MOUNTED EQUIPMENT. This paragraph establishes general design, performance, and interface requirements for all Labcraft equipment to be mounted in the Spacelab pressurized module.

3.4.1 Physical requirements. This paragraph defines the physical requirements and constraints imposed on equipment to be mounted in the module.

3.4.1.1 Structural attachment. Module equipment may be installed in one of the following ways:

- (a) In Spacelab-provided racks
- (b) In special Labcraft racks
- (c) In other Labcraft structures which attach to the Spacelab floor, and dome, or other approved locations
- (d) In existing Spacelab stowage containers.

3.4.1.1.1 Additional on-orbit mounting of equipment is possible, including attachment to airlocks, optical windows, or to other Spacelab or payload equipment. However, such mounting configurations shall not be used for the ascent and descent flight phases. All mounting methods must comply with the load limits defined in 4.1 of Reference 2.2.1(b), and shall be designed to survive the loads defined in 5.2 of Reference 2.2.1(b). The factor of safety used in the design shall be conservative so as to

reduce the testing requirements and, correspondingly, the total cost of a qualified flight structure. The required factors of safety are:

- (a) Yield load = 2.0 by limit load and ultimate load  
= 3.0 by limit load.

3.4.1.2 Occupied volume. The total volume available inside the module is nominally constrained as described in 2.2.1(b) and consists of the following areas:

- (a) Rack space
- (b) Ceiling storage
- (c) Center aisle installation.

In defining the module configuration, reasonable allowance must be made for unrestricted crew movement and working conditions. Reference 2.2.1b defines the module volume available for payload equipment in more detail.

3.4.1.3 Handling provisions. Equipment which must be moved, deployed, or otherwise detached from the basic supporting structure shall include tiedowns, detents, handles, and other features necessary to insure safe and efficient on-orbit operation.

3.4.1.4 Environments. Module equipment shall be designed to operate and to survive (non-operating) the environments anticipated during various flight phases as defined in 5.2 of Reference 2.2.1b.

3.4.1.5 Alignment. All alignment required by the Labcraft payload shall be provided by the payload equipment. The Orbiter/Spacelab does not have any capability for providing a reference for physical alignment. (However, the Orbiter GN&C can provide Orbiter or a target state vector data in a variety of coordinate systems. Alignment errors between the Orbiter IMU and the payload are expected to be at least two degrees.

3.4.2 Electrical requirements. This paragraph contains the electrical requirements imposed on equipment to be mounted in the module.

3.4.2.1 Electrical power. Electrical power is available from three separate busses:

- (1) A 28-volt DC essential bus (limited to 25 watts for the total Spacelab payload)
- (2) A second 28-volt DC bus
- (3) A three phase 115/200 volt 400 Hz AC bus.

All payload power is distributed via Spacelab electrical power distribution boxes. There is one box in the core segment and one in the experiment segment. Up to 1350 watts of power may be provided to the payload during ascent/descent. All power to Spacelab is controllable from the Orbiter AFD. In addition, each equipment item or assembly may have its power controlled manually from a panel in the module or automatically via the CDMS. Fault protection for module equipment shall be provided in accordance with the safety requirements of TBD.

3.4.2.2 Electrical signals. Electrical signals (data and commands) to or from Labcraft equipment installed in the Spacelab pressurized module may be routed via the following paths:

- (a) Directly to other payload equipment in the module, on the pallet, or on the OAFD
- (b) Indirectly via an RAU to the Spacelab CDMS and then to any of the above equipment locations or to the Spacelab data storage or to the Orbiter communication link. Definition of the CDMS/RAU interface is given in Reference 2.2.1b.

All equipment in the module shall include provisions for indicating state-of-health as well as operating mode.

3.4.2.3 Ground and shielding. Module equipment shall conform to the ground and shielding techniques specified in TBD of Reference TBD.

3.4.2.4 Interconnecting cabling. All interconnecting cabling to or between payload equipment must be provided as part of the payload. All direct wiring or coaxial cabling from the payload to Spacelab or Orbiter must also be provided. All cabling installations must include tiedowns and thermal protection. Cables which interface with existing Spacelab equipment must incorporate compatible connectors as defined in TBD of Reference TBD.

3.4.3 Field of view. Equipment requiring a field of view external to the module must be designed to operate through existing Spacelab apertures. There are basically three openings in module:

- (1) A 1.3 meter diameter opening in the top of each module segment. This opening can accommodate either a scientific airlock or an optical window
- (2) A 0.4 meter viewport on the conical section of the aft end dome.

3.4.4 Thermal control. Labcraft equipment mounted in the Spacelab module must satisfy the constraints defined in 4.3.2 of Reference 2.2.1(b). The Spacelab provides three basic methods for thermal control inside the module:

- (1) The Spacelab avionics air loop
- (2) A water loop
- (3) The cabin air loop, limited to 1 kilowatt of payload heat.

In addition, Spacelab provides four thermal capacitors and two cold plates to accommodate peak thermal loads.

3.4.5 Electromagnetic compatibility. All Labcraft equipment shall be compatible with the requirements of specification [2.2.2(g)].

3.4.6 Electric and magnetic fields. The design of Labcraft payload equipment shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produced by the specific payload unit, by other payload components, or by the Spacelab/Orbiter vehicle. Further, Labcraft equipment shall not create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.

3.4.7 Testing. Ground testing of module equipment shall be accomplished via the module flight cabling and preferably via the Spacelab CDMS. There shall be no direct cable tie from GSE to Labcraft equipment in the module once the payload is installed in the Orbiter, except that such connections may be permissible to accomplish post-flight calibration. On-orbit testing may encompass function verification, instrument calibration, and fault isolation for those units that are repairable or that may be replaced with spare units.

3.4.7.1 Ground support equipment (GSE). Module equipment design shall include provisions for interfacing with appropriate mechanical and electrical GSE required to support integration, ground transportation, and prelaunch operations.

3.4.8 Operational requirements. Labcraft module equipment design shall include consideration of the operational nature of Spacelab payloads. This shall include both ground and flight activities as specified below.

3.4.8.1 Crew interfaces. Module equipment design shall incorporate features to exploit the technical training and manual skills of the Spacelab crew where such design can improve experiment operation or reduce payload cost. The crew should not be required to perform dull, routine, tedious tasks for extended periods nor required to accomplish tasks requiring extraordinary manual skills. To facilitate crew training Labcraft control and display consoles should follow the general design techniques employed in the basic Spacelab CDMS.

3.4.8.2 Integration. Module equipment shall be designed to meet the constraints imposed by the proposed Spacelab payloads integration process. Among these constraints are the following:

- (a) Limited schedule (may be as short as TBD days) for all launch site integration (levels III/II and I)
- (b) Limited access following level I integration
- (c) Class 100,000 cleanliness shall be maintained during all integration activities. Where this cleanliness level is not adequate, the individual instrument must provide its own environmental cover
- (d) Level IV may not occur at the launch site; hence the module equipment must include a transportation environment
- (e) Payload equipment is installed in a horizontal Orbiter and erected vertically prior to launch; vertical payload removal may be required using vertical access equipment.

3.5 ORBITER AFT FLIGHT DECK (OAFD) EQUIPMENT. Labcraft payloads may require control, display, or other equipment to be installed on the OAFD. Such equipment must satisfy the requirements specified below.

3.5.1 Physical requirements. This paragraph describes the general physical requirements and constraints imposed on OAFD equipment.

3.5.1.1 Structural attachment. OAFD equipment attachment to the basic Orbiter support structure will be via approved methods to be specified by NASA/JSC. The NASA will also specify the allowable loading for each of the separate OAFD panel areas.

3.5.1.2 Stowed volume. The panel dimensions, total panel area, and stowed volume for all OAFD equipment shall conform to the constraints set forth in Paragraph 11.1 of Reference 2.2.1c. The assignment of specific panel space to Labcraft equipment will be made by the cognizant payload lead center.

- 3.5.1.3 Environments. OAFD equipment shall be design to operate and/or survive the applicable environmental factors defined in Paragraph 4 of Reference 2.2.1c.
- 3.5.2 Electrical requirements. This paragraph specifies the electrical design and interface requirements for OAFD equipment.
- 3.5.2.1 Electrical power. The total power available for OAFD payload-unique equipment shall not exceed 350 watts average during all prelaunch, ascent, descent, and post-flight operations. On orbit the Orbiter will provide 750 watts average and 1000 watts peak for payload OAFD equipment. This power is not chargeable to the payload; however the energy consumed is payload chargeable. This power is 28 volts DC direct from the Orbiter fuel cells. Additional power (e.g., 115 volts 400 Hz) can be made available from the Spacelab power distribution system.
- 3.5.2.2 Connectors. OAFD equipment shall be designed to interface with the standard set of connectors defined in Paragraph 11.1.3 of Reference 2.2.1c.
- 3.5.2.3 Interconnecting cabling. Cabling between the OAFD equipment and Spacelab may include single wire, twisted shield wire pairs, or coax. Spacelab-Orbiter cabling interfaces are defined in Paragraph 12.2.5 of Reference 2.2.1c. Cabling between units on the OAFD must comply with the space limitations inherent in the console layout.
- 3.5.2.4 Circuit protection. OAFD equipment must include circuit protection devices to protect payload-unique wiring and equipment as well as to prevent the propagation of hazardous conditions.
- 3.5.2.5 Grounding and shielding. OAFD equipment shall conform to the grounding and shielding practices defined in TBD of Reference TBD.
- 3.5.3 Electromagnetic compatibility. OAFD equipment shall comply with the applicable portions of JSC Specification SL-E-0002, "Electromagnetic Characteristics, Requirements for the Space Shuttle Program."
- 3.5.4 Thermal control. Cooling is provided to OAFD equipment by forced air from the Orbiter environmental control and life support system. Standard 1/2 inch (38 mm) duct connections are provided.
- 3.5.5 Electric and magnetic fields. The design of Labcraft payload equipment shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produced by the specific payload unit, by

other payload components, or by the Spacelab/Orbiter vehicle. Further, Labcraft equipment shall not create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.

- 3.5.6 Testing. Ground testing of OAFD equipment following installation in the Orbiter may be accomplished by connecting GSE directly to the Orbiter service panels on the forward payload bay bulkhead. Additional pre-flight testing shall be carried out via the Spacelab CDMS and the normal payload umbilical service.
- 3.5.6.1 Ground support equipment (GSE). OAFD equipment design shall include provisions for interfacing with appropriate mechanical and electrical GSE required to support integration, ground transportation, and pre-launch operations.
- 3.5.7 Operational requirements. OAFD equipment must comply with the operational constraints imposed by the space shuttle system both on the ground and while in flight. The basic requirements for OAFD equipment may be established through detailed analyses or may originate from consideration of crew convenience. Equipment functions may include control, display, data process, data storage, caution and warning, or any function compatible with OAFD resources.
- 3.5.7.1 Integration. OAFD equipment shall be designed to meet the constraints imposed by the proposed Spacelab payloads integration process. Among these constraints are the following
- (a) Limited schedule (may be as short as TBD days) for all launch site integration (levels III/II and I)
  - (b) Limited access following level I integration
  - (c) Class 100,000 cleanliness shall be maintained during all integration activities. Where this cleanliness level is not adequate, the individual instrument must provide its own environmental cover
  - (d) Level IV may not occur at the launch site; hence the AFD equipment must include a transportation environment
  - (e) Payload equipment is installed in a horizontal Orbiter and erected vertically prior to launch; vertical payload removal may be required using vertical access equipment
  - (f) Equipment must be modularized so that no single unit weighs more than TBD kilograms, and must be

provided with more handling aids to facilitate installation into and removal from the Orbiter via existing hatches with the Orbiter in a horizontal position.

### 3.6 FLIGHT SOFTWARE

- 3.6.1 Purpose. The Labcraft flight software requirements defined in this section shall permit control and monitoring of the performance of Labcraft experiments in flight and provide features as are required to support Labcraft ground testing as well as in-flight testing and training activities.
- 3.6.2 Compatibility. Labcraft flight software shall be compatible with the Spacelab CDMS and with associated support software delivered by ESA. It shall be capable of controlling transmission of experiment data destined for ground analysis. It shall be capable of receiving and processing Labcraft ground commands and associated data transmitted via the Orbiter interface. Labcraft flight software shall be compatible with Orbiter software for all data exchanges between Spacelab and Orbiter-mounted equipments.
- 3.6.3 Residence. The Labcraft flight software shall reside in the CDMS experiment computer and its peripherals.
- 3.6.4 Modularity. Labcraft flight software instructions and data packages relating specifically to each instrument, FSE, and specifically to each experiment using these, shall be designed such that they can be individually inserted and removed without requiring significant redesign or reconfiguration effort.
- 3.6.5 Language. The Labcraft flight software shall be written in a NASA-approved programming language. Currently, approved languages are HAL/S, FORTRAN (ANSI x 3.9 - 1966) and CII 125S assembly language, and GOAL.
- 3.6.6 Software standards. The Labcraft flight software shall comply with the software standards and guidelines issued for this purpose.
- 3.6.7 Responsiveness. Labcraft flight software shall delay no more than 2 seconds in responding with feedback to any operator command due to delays within the Labcraft flight software.
- 3.6.8 Operator convenience. Labcraft flight software shall minimize the flight operator's keyboard and other input control manipulations required.



- 3.6.9 Visibility. Labcraft flight software shall provide the operator with sufficient visibility to judge the quality of experiment performance. It shall provide him with such error messages as are practical to advise him of errors or out-of-tolerance conditions.
- 3.6.10 Command language convenience. Labcraft flight software shall contain easy to use command subroutines or macros to assist in the convenient development and test of the flight software.
- 3.6.11 Load check. Labcraft flight software shall contain the capability of verifying the correctness of the software loaded for both ground test and flight purposes.
- 3.6.12 Uplink commands and data. Labcraft flight software shall be capable of accepting uplinked commands and data that are properly identified and headed.
- 3.6.13 In-flight modification. Labcraft flight software shall be capable of accepting modifications to programs and data from the ground that are properly identified and headed.
- 3.6.14 Damage or serious delay prevention. Labcraft flight software shall contain provisions to prevent equipment damage or serious delays in the performance of the experiment mission.
- 3.6.15 Data acquisition management. Labcraft flight software shall enable the operator to time and sequence the acquisition of data from Labcraft payloads.
- 3.6.16 Display management. Labcraft flight software shall support the display of science, housekeeping, operational status, time, state vector, and error conditions in connection with the test and operation of Labcraft experiments.
- 3.6.17 Data quality assignment, annotation. Labcraft flight software shall enable the operator to assign data quality bits and/or make data annotation to all science data and performance data being preserved for future analysis.
- 3.6.18 Test functions. Labcraft flight software shall contain such entry points, exit points, and logic as are necessary to permit ground and in-flight testing and simulations to be performed.
- 3.6.19 Operators supported. Labcraft flight software shall support a maximum of three CRT-keyboard combinations on board, and the associated panel lights, switches, and other operator controls.

- 3.6.20 Modes of operation. Labcraft software shall support the following modes of operation (1) manual step-by-step, (2) piece-wise automatic, and (3) fully automatic. Items (2) and (3) shall be subject to override at operator's choice.
- 3.6.21 Save-experiment state. Labcraft flight software shall be capable of preserving the state of an experiment such that it may be resumed after interruption without significant delays due to reinitialization of the previous state.
- 3.6.22 Operator overrides, restart. Labcraft flight software shall permit the operator to override: (1) error alarms no longer desired, (2) error branches that interfere with experiment operation, and (3) values of constants that are no longer applicable. The operator shall be capable of restarting the software at preplanned restart points.
- 3.7 LABCRAFT TRAINING EQUIPMENT. Training on the use of Labcraft equipment for payload specialists and other flight crew members shall be provided for the following purposes:
- (a) Equipment familiarization
  - (b) Experiment procedures
  - (c) Experiment planning and replanning
  - (d) Consumables management
  - (e) Labcraft/Spacelab interfaces
  - (f) Joint/coordinated operations.
- 3.7.1 The training equipment and facilities required will include special training equipment, classrooms, flight hardware, GSE, and spares.
- 3.7.2 The need for special equipment shall be minimized by using flight hardware, spares, and existing mockups to the maximum extent feasible.
- 3.7.3 Habitability and safety training and Orbiter/Spacelab familiarization will be provided by the Orbiter and/or Spacelab programs. Responsibility for training in the operation of Spacelab/Labcraft interface equipment will be shared between the Spacelab and Labcraft projects.
- 3.8 LABCRAFT GROUND SUPPORT EQUIPMENT. Each separate unit of Labcraft flight equipment as well as integrated Labcraft payloads shall have supporting ground equipment. This dedicated GSE shall, as a minimum, satisfy the following functional requirements:
- (a) Ground hoisting/handling
  - (b) Ground transportation

- (c) Environmental protection
- (d) Work stands or other integration aids
- (e) Prelaunch checkout
- (f) Ground power.

Additional GSE may be required to satisfy functions such as loading of expendables, equipment alignment, storage, prelaunch or post-launch calibration, and interface verification.

3.8.1 General requirements. In order to minimize the cost of dedicated GSE, the following requirements shall apply to all Labcraft GSE.

3.8.1.1 Use of existing equipment. Before developing specialized Labcraft GSE, the inventory of ground equipment available from other programs, particularly other Spacelab payload programs, shall be considered for potential usage. In addition, the use of commercial/existing components and/or the use of factory test equipment shall be considered in lieu of specialized units to satisfy Labcraft requirements.

3.8.1.2 Multiple usage. Insofar as possible, GSE shall be designed to satisfy requirements at all levels of integration.

3.8.1.3 Transportability. GSE shall be designed to meet the same transportation requirements as the Labcraft payload (see 5.0).

3.8.1.4 Safety. The design of all GSE shall include consideration of safety requirements and the reduction of hazards to ground personnel as outlined in 3.9.5 below.

3.8.1.5 Reuseability. Labcraft GSE shall be designed for reuse, and particular attention shall be given to growth in capabilities, to repair and refurbishment, and to component wearout or life characteristics.

3.8.1.6 Interfaces. GSE shall be compatible with the following interfaces:

- (a) Labcraft flight equipment
- (b) Level IV, III, II, AND I facilities
- (c) Orbiter and Spacelab.

In particular, Labcraft GSE design must reflect the manned aspects of payload design, the flight software, the cleanliness requirements of Spacelab, the schedule constraints of Orbiter payload integration, and the limited access to payloads during launch site integration.

- 3.8.2 Construction standards. Labcraft GSE shall use parts, materials, and processes compatible with the usage environment and consistent with accepted commercial and aerospace standards for similar equipment.
- 3.8.3 Environments. GSE may be subject to any of the following operating and non-operating environments. Exposure may be repeated through various cycles and may involve extended periods of time.
- 3.8.3.1 Operating environment. The nominal GSE operating environment will be within the values defined in Table III-I.
- 3.8.3.2 Transportation environment. GSE may be exposed to any or all of the environmental factors specified in Table III-I.
- 3.8.3.3 Storage environment. GSE shall be designed to survive (without damage) exposure to the storage environment identified in Table III-I.

Table III-1. GSE Environments

Environmental Parameter	Units	Parameter Value Versus Condition		
		Operating	Transportation	Storage
Temperature	$^{\circ}\text{C}$	TBD	TBD	TBD
Pressure	$\text{kg}/\text{cm}^2$	↓	↓	↓
Relative humidity	%			
Acceleration	G			
Vibration	$\text{G}^2/\text{Hz}$			
Shock				
Cleanliness		↓	↓	↓

3.8.4 Electrical requirements.

- 3.8.4.1 Electromagnetic compatibility. All GSE shall be designed to minimize the output of spurious radiated or conducted interference and shall be designed to isolate or minimize the effects of externally generated interference. As a minimum, all GSE shall meet the requirements specified in TBD.
- 3.8.4.2 Fault protection. All GSE shall include circuit breakers, fuses, or other devices to protect flight equipment and the GSE from damage due to shorts, grounds or other circuit faults.
- 3.8.4.3 Electrical power. Labcraft GSE shall be designed to operate from commercial 60 Hz power sources operating at a nominal 110/220 volts with either single or three phase power available.

- 3.8.4.4 Ground. EGSE shall be designed to comply with the applicable portions of OSHA safety standards, other governmental wiring regulations, the National Electrical Code, and the specific characteristics of the Labcraft payload, the Spacelab, and/or the Orbiter vehicle as well as any local facility characteristics. Safety considerations shall not be compromised in the configuration of a GSE ground scheme.
- 3.8.4.5 Orbiter interfaces. EGSE interfaces with the Labcraft payload installed in the Orbiter shall be via existing payload umbilicals defined in Paragraph 4.10 of Reference 2.2.1c.
- 3.8.4.6 Spacelab interfaces. Labcraft GSE shall use the existing Spacelab CDMS capabilities to carry out payload checkout wherever possible and providing it is the most economical approach.
- 3.8.5 Controls and displays. GSE may utilize the Spacelab CDMS controls and displays for Level III/II and Level I integration. However, a separate capability must be provided for Level IV integration.
- 3.8.6 Software. Checkout software operating through the GSE may be required during integration or prelaunch checkout to satisfy schedule constraints or to meet technical objectives. Low cost shall be a principal consideration in the selection and formulation of checkout software, and commonality of language, subroutines, and hardware (computers, compilers, etc.) will be a key objective in achieving low cost.
- 3.8.7 Performance. GSE shall have a performance capability compatible with the system requirements. Factors of safety will apply to mechanical equipment design. For electrical GSE, performance parameters such as measurement accuracy shall include design tolerances to allow for operator error, degradation of calibration, aliasing errors, digitizing errors and other anticipated error sources. All GSE should reflect consideration of the operating personnel in terms of ease of operation, use of unambiguous controls and data presentation, and judicious use of automatic sequencing. Where feasible, GSE should include built-in calibration sources and should also indicate when faults or out of tolerance conditions are present.

### 3.9 MISSION ASSURANCE

#### 3.9.1 Reliability

##### 3.9.1.1 Reliability requirements for flight hardware. Labcraft equipment shall be consistent with the following reliability goals:

- (a) No single point failure shall result in loss of a major portion of the objectives of a flight.
- (b) No second failure in the same hardware element shall preclude successful abort of the mission.
- (c) Fault isolation shall ensure that an equipment failure does not affect the performance of other instruments or other Labcraft equipment.
- (d) Fault isolation provisions shall ensure that a single failure will not result in any of these conditions:

Nullify system redundancy

Require extensive or immediate crew intervention.

- (e) Redundancy provisions, where crew safety and overall flight objectives are affected, shall be implemented as follows:
  - Active redundancy or automatic redundancy switch-over for any failure condition which would preclude meeting the reliability design goals delineated in this section.
  - Standby redundancy for all other conditions which are consistent with routine fault isolation and maintenance provisions.

##### 3.9.1.2 Reliability requirements for Labcraft GSE. A ground support equipment failure shall not result in damage to flight hardware.

##### 3.9.1.3 Reliability analysis. A system level Failure Mode and Effects Analysis (FMEA's) shall be performed to determine the effects of component failures on crew safety and the accomplishment of flight objectives. Analysis results will then be categorized by criticality and summarized on a critical items list.

### 3.9.2 Maintainability

#### 3.9.2.1 Maintainability requirements. Labcraft equipment and instruments shall be consistent with the following maintainability goals:

- (a) All hardware shall be designed for a service life of 20 missions of 7 to TBD days/mission. This service life may extend over a period of 10 years and the equipment may fly as often as three times per year. To meet this service life, the equipment shall be designed with low cost maintenance and refurbishment features included.
- (b) All hardware shall provide for maximum interchangeability and replaceability and shall be modular in concept.
- (c) Limited life hardware elements shall be minimized to the fullest extent possible.

#### 3.9.2.2 Maintainability requirements for in-flight maintenance.

- (a) On-orbit maintenance in Spacelab shall be limited to:
  - Replacement of readily accessible elements to correct easily isolated problems
  - Replacement of redundant elements affecting crew safety and overall mission objectives
  - Use of standard hand tools and off-the-shelf test equipment normally contained within the Spacelab
  - No alignment of elements after replacement
  - The mean-time-to-repair (MTTR), based on line replaceable unit replacement, is 1 hour (see Paragraph 1.4.7 of Reference 2.2.1a).
- (b) Pallet-mounted items shall be excluded from in-flight maintenance.
- (c) The onboard fault detection system shall have the following characteristics:
  - Fault identification to the line replaceable unit
  - Display of all out-of-tolerance conditions by unit and parameter which affect crew safety or flight objectives
  - Fault conditions affecting crew safety shall also activate the caution and warning panel.

### 3.9.2.3 Maintainability requirements for ground maintenance.

- (a) Line replaceable unit replacement during Level IV, III, or II ground operations.
- (b) Equipment requiring servicing between flights shall be designed such that all elements requiring maintenance shall be readily accessible, thereby precluding major disassembly of the equipment, or removal of other equipment.
- (c) Status bits shall be routed to a flight connector for each unit which permits a positive determination of the unit's functional status. These status bits shall be capable of being monitored by ground support equipment.

### 3.9.3 Material and process control requirements.

3.9.3.1 Purpose of material and process control. Material requirements and controls will be imposed on all materials of construction for Labcraft equipment. These restrictions are for the purpose of ensuring personnel and mission safety, to ensure experiment reliability and efficiency, and to prevent detrimental effects on Spacelab, Orbiter, and pallet equipment. The following specific material properties will be controlled (see 1.4.5 of Reference 2.2.1(a)).

- (a) Offgassing of possibly toxic or odorous trace contaminants from materials used inside the habitable area of the Spacelab or Orbiter
- (b) Flammability of materials which can result in fire hazards inside the Orbiter
- (c) Outgassing products from materials exposed to vacuum, which may interfere with the correct function of other experiments or equipment
- (d) Corrosion or material compatibility which may affect the correct operation of the experiments or equipment. Stress-environment interactions which could result in premature failure of components or structure will also be controlled.
- (e) Specific properties of "Forbidden Materials" or "Restricted Materials," as listed in 3.9.3.4, which can be dangerous to personnel or mission safety or are known to cause extreme contamination.



3.9.3.2 Location requirements for specific material characteristics. For the purpose of defining relevant material requirements, the following areas in which Labcraft equipment may be flown shall be distinguished:

- (a) Habitable areas. Materials exposed to the atmosphere of the habitable areas, including the Orbiter flight deck, the Spacelab habitable area, and the airlocks shall not off-gas toxic or odorous products at the expected worst case temperatures, and the Orbiter flight deck materials shall be nonflammable in an atmosphere of 23.8 percent  $O_2$  and 1 atmosphere pressure.
- (b) Spacelab pallets. Materials used in pallet-mounted Labcraft equipment shall have low-outgassing properties in vacuum.
- (c) Sealed containers. No specific requirements are imposed on materials used inside sealed containers providing such containers do not rupture and emit gasses or flames under expected worst case conditions including an internal ignition.
- (d) General locations. The requirements on corrosion, material compatibility, forbidden materials, and restricted materials, as defined under 3.9.3.3 and 3.9.3.4, are applicable independent of Labcraft equipment location.

3.9.3.3 Corrosion and materials compatibility.

- (a) Dissimilar metals. No dissimilar metals, as defined in Reference 2.2.3(b), shall be used in contact with one another
- (b) Stress corrosion cracking. Reference 2.2.3(c) shall be used to control stress levels in materials susceptible to stress corrosion cracking
- (c) Pressure vessel materials. Materials used in pressure vessel construction will conform to the requirements of Reference 2.2.3(d).
- (d) Moisture and fungus resistant materials. Materials which are nutrients for fungus, as defined in Reference 2.2.2(d) and/or Reference 2.2.3(f), shall not be used except in hermetically sealed assemblies or if properly surface coated and tested per Reference 2.2.3(f). Fungus inert materials are listed in Reference 2.2.3(g), requirement 4. Material properties shall not degrade following repeated exposures to moisture. Any materials which absorb moisture, and hence require bake-out or some similar drying process, shall be so identified and approved prior to use.

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- (c) Particulate contamination. Labcraft equipment shall be designed so that its contribution to the particulate contamination of the air in habitable compartments, when combined with the contributions from Spacelab/Orbiter equipment and experiment equipment, shall not cause the resultant total particulate contamination to exceed (TBD).

#### 3.9.4 Safety

- 3.9.4.1 General system safety requirements. The System Safety Policy for the Labcraft equipment payload is to require the minimum safety requirements that will logically protect flight and ground personnel, the public, property, environment, elements of the transportation system during ground operations, normal landings, crash landings, aborts, flight emergency operations and normal flight operations, and emergency payload operations.
- 3.9.4.1.1 All specific or potential hazards which have the potential of inflicting injury to personnel or damage to equipment or property shall be controlled such that a safe interface between personnel and systems of concern exists in the presence of the hazard; a hazard is defined as the presence of a potential risk situation caused by an unsafe act or condition. All existing or potential hazards which cannot be controlled shall be classified as uncontrolled catastrophic or critical residual hazards.
- 3.9.4.1.2 All residual catastrophic and critical hazards must be approved by Labcraft equipment program management for inclusion in the system design and operations.
- 3.9.4.1.3 The Labcraft equipment safety requirements must adhere to all the requirements found in Reference 2.2.2(a). The safety requirements delineated in Reference 2.2.2(b) will be used as a guideline.
- 3.9.4.1.4 Additional general system safety requirements are:
- (a) No single point failure will adversely affect safety of the crew and no second failure in the same equipment will preclude successful abort of the mission
  - (b) The system will be designed as a minimum to be fail-safe
  - (c) Safety-critical redundant equipments shall be separated to prevent hazard propagation to the maximum extent practicable.
- 3.9.4.2 Specific safety requirements for flight systems. The Labcraft equipment system design shall adhere to the specific safety requirements in the following paragraphs.

- 3.9.4.2.1 Flight operations. (a) The Labcraft equipment system shall not impose restrictions on normal or contingent Space Shuttle operations (including intact abort and rescue operations) in which the safety of the Space Transportation System (STS) or flight personnel may be affected. Equipment must have the capability of being returned to a safe or inert status at the termination of the experiment operations, including emergency shut-down provisions in the case of hazardous conditions.
- (b) When equipments require some operation during ascent and reentry, they must not require any command action from the ground or the Shuttle crew during the powered flight phase except safing commands.
- 3.9.4.2.2 Free flying and retrievable items. (a) Free-flying items shall have command and control circuitry associated with their launching/propulsion systems which are designed to preclude inadvertent launch or firing in case of hardware failure.
- (b) Free flying items which contain hazard sources (e.g., explosive devices) shall be designed such that their hazard producing functions are positively inhibited until at a safe distance from the Orbiter.
- (c) Retrievable free flying items shall include provisions to permit pre-retrieval safing which can be verified by the Orbiter and ground crews prior to the performance of retrieval operations.
- (d) The hazards of intercepting a free flying item (satellite, instruments, etc.) shall be controlled by TBD.
- (e) Items extended outside the Orbiter payload bay envelope or outside Spacelab airlocks must have a capability for emergency ejection and/or retraction. This capability shall be provided by a dedicated system capable of control from the Spacelab and Orbiter.
- (f) Items incapable of being properly stowed (be able to withstand crash landing loads) before landing of the Orbiter and that would be a potential hazard to the Orbiter shall have a redundant stowage mechanism or be capable of being ejected before reentry.
- (g) Residual material following emergency retraction or ejection shall not interfere with the closure of Orbiter cargo bay doors or scientific airlock hatches.

- 3.9.4.2.3 Controls. (a) All switches shall be recessed or otherwise protected against accidental actuation.
- (b) A rapid means of switching off power under emergency conditions shall be provided.
  - (c) Automated control functions shall have manual override provisions.
  - (d) All safety-critical command and control circuitry associated with engine firing, primary propulsion systems or auxiliary propulsion systems shall be designed to preclude inadvertent firings in case of initial hardware failures.
  - (e) Safety control functions (command override, emergency control provisions, etc.) shall derive their power from a source independent of the primary power supply.
- 3.9.4.2.4 Software. (a) The software shall conform to the following requirements TBD.
- 3.9.4.2.5 Caution and warning (C&W). (a) The capability shall be provided for redundant transmittal to the Orbiter caution and warning system of that data which is critical to the safety of the STS or its flight personnel. Redundant sensors are required to sense all hazardous conditions.
- (b) The C&W system shall monitor all safety critical parameters and any payload equipment functions that have the potential of endangering the crew.
  - (c) Fire sensors (detectors) shall be located to provide coverage of all potential fire areas of the Labcraft equipment system.
  - (d) The C&W system shall be operative during all mission phases. All safety-critical system functions and equipment shall be capable of being activated, controlled and deactivated from the Orbiter during all flight phases.
  - (e) Any actual or impending anomalous condition which in combination with other failures could be hazardous to the STS or flight personnel and requires timely crew action shall be monitored by the "caution" function of the C&W system.
  - (f) During ground operations, C&W signals shall also be displayed by ground support equipment.

- (g) For every C&W signal provided, there must be a means available to correct the problem. In general, the C&W system is not to be used as an information system. Appropriate controls for safing the Labcraft equipment or controls operationally required for "command Override" of safety critical functions shall be defined.
- (h) The design of the C&W system shall include its signals being monitored from the ground during flight operations.
- (i) All caution and warning indications shall be provided inside the Spacelab and, independently, inside the Orbiter.
- (j) Instrumentation shall be adequate to provide timely indication of hazardous out-of-tolerance conditions, and provision made to correct such conditions prior to the condition becoming a hazard to the crew, the Orbiter or Spacelab.
- (k) In the case of free flying payloads, when they are being deployed, retrieved, or checked out (within the "sphere of influence" of the Orbiter) the preferred mode of operation will be under the control of the Mission Control Center-Houston. There shall, however, be a capability of displaying safety critical, caution and warning types of information from the payload to the Orbiter crew. There shall also be a capability of sending safing commands from the Orbiter directly to the free flying payload to assure crew safety of the Orbiter crew (e.g., avoid collision).
- (l) For those hazards that may result in time-critical emergencies, provisions shall be made for alerting the crew by visual and audible caution and warning signals (a time-critical emergency is the result of a malfunction that must be detected and corrective action initiated within less than 5 minutes to prevent failure of a critical function). Automated control functions shall have manual override provisions.
- (m) All sensors for all parameters monitored by the C&W system shall be independently powered by the C&W system to prevent loss of hazard indication due to power failure of a monitored system.
- (n) The C&W system shall monitor its own performance and alert the crew to out-of-limit conditions, including loss of primary power.
- (o) An inhibit switch shall be provided in each sensor circuit to allow isolation of a single malfunctioning sensor and permit normal operation of all other remaining sensing units.

- (p) All sensors used for inputs to systems other than C&W which are also used by the C&W system, shall be isolated such that a failure in the other system will not affect the caution and warning system.
- (q) All C&W system sensors shall fail in such a manner that a signal input will be initiated to the C&W system, resulting in an indication of sensor failure.
- (r) All elements of the caution and warning system required to function after module emergency depressurization must be vacuum qualified.
- (s) The caution and warning system shall be sufficiently redundant in itself to prevent any single point of failure from disabling the system.
- (t) Provision shall be made to perform end-to-end check of critical caution and warning system functional paths up to sensor interface, whenever possible, provision will be made to check the sensor function, range, and/or sensitivity.

3.9.4.2.6 Material — flammable, toxic, corrosive, fragile. (a) The materials used shall adhere to the safety requirements specified in 3.9.3 Material and processes control requirements, and 3.9.5 Parts selection, of this document and to the following additional material safety requirements.

- (b) Flammable materials exposed to the ambient atmosphere shall be separated to prevent flame propagation paths. Similarly, separation of flammable materials from possible ignition sources is required to the maximum extent practicable. Consideration shall be given to:
  - (1) Reduction in the probability of ignition
  - (2) Restriction of any fire to a definable area
  - (3) Limitation of the rate and magnitude of the rise of temperature and pressure from any fire to prevent the loss of structural integrity
  - (4) Single barrier failures.
- (c) Toxic, corrosive and/or flammable materials shall be stored and used such that failure of the primary container will not release the material into the cabin atmosphere. Provision shall be made for the safe collection and storage of used or spent materials, considering also their possible chemical or physical interaction. Use of the Orbiter vent system may be considered.

- (d) Toxic materials and other materials determined by analysis and/or test to be hazardous (toxic, corrosive in odor producing) must be isolated from the crew and cabin system, and suitable measures for neutralization provided in case of hazard.
- (e) Where hazards can occur due to the presence or contact of mutually incompatible materials, components at electrical differences or of chemically incompatible substances or incompatibility with oxygen, such components or substances shall be separated to the maximum practical extent.
- (f) Hazardous fluids shall normally be dumped or vented overboard prior to reentry. If this capability cannot be utilized, the hazardous fluid containment shall be designed to remain intact under crash loads with assurance provided that tank integrity will not be violated by other equipment due to impact as a result of crash loads.
- (g) The system components inside the Spacelab that require venting shall vent by-products into the Spacelab experiment vent system.
- (h) Material which can shatter shall not be used in the module unless positive protection is provided to prevent fragments from entering the cabin environment. Photographic and optical equipment which cannot comply with this standard must be protected by suitable covers when not in use.

3.9.4.2.7 Consumables. (a) Cryogenic materials must be stored external to the Spacelab module shell in containers with adequate safety margins and venting provisions for flight and ground operations. Other consumable and cryogenic safety requirements are TBD.

3.9.4.2.8 Explosive. (a) Explosive devices capable of producing fragments or significant environment overpressure shall meet the requirements of Reference 2.2.2(e).

- (b) Safety requirements for shape charges and solid rocket motors are TBD.
- (c) Destruct systems shall not be used.
- (d) Any explosive or pyrotechnic devices used for the jettison of hardware should be designed to be fail-operational/fail-safe.



- 3.9.4.2.9 Electrical. (a) High voltage systems shall be suitably insulated, isolated. Provisions for automatic cutoff of high voltage is required when access to high voltage equipment for adjustment, maintenance or repair is needed.
- (b) Experiment grounding shall be such as to preclude electrical discharge hazards and shocks.
- (c) Consideration shall be given to the control of potential explosive rupture of electrical/electronic components such as batteries and capacitors and other electrical hazards that could cause damage or injury to personnel or the elements of the Space Transportation System.
- 3.9.4.2.10 Pressure vessels. Pressure vessels shall be in accordance with Reference 2.2.2(f) or in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2. If pressure vessels are used which are not in accordance with NSS HP 1470.1, then these pressure vessels must be tested to demonstrate fluid compatibility of the vessel with the contained fluid per NSS HP 1740.1. Pressure vessels shall normally be installed exterior to the Spacelab cabin, and suitable regulation, pressure relief, and flow restriction provided so that flow into the cabin is limited to the capability of the Spacelab vent system. Small pressure vessels may be permitted inside the cabin provided they do not have a credible explosive failure mode and their failure will not expose the crew or vehicle to hazard. A safe margin of 4 to 1 should be used in the design of all pressure vessels internal to the cabin.
- 3.9.4.2.11 Mechanical equipment. Mechanical devices such as springs, springloaded levers, and torsion bars, which are capable of storing energy, should be avoided in experiment design. Where stored mechanical energy devices are absolutely necessary, safety features such as locks, protective devices, and warning placards shall be provided. Rotating machinery must be protected by suitable guards. Where machinery is highly stressed, containment for possible failure must be provided. Exposed sharp corners, edges and protrusions shall be avoided.
- 3.9.4.2.12 Electromagnetic compatibility. All system/equipments or functions installed in or associated with the Spacelab or Orbiter shall be classified as EMI Critical if their failure or unintended operation could cause one or more of the following:

Loss of life or injury to flight or ground crew.

The system/equipment shall be designed per the safety requirements of Reference 2.2.2(g).

- 3.9.4.2.13 Non-ionizing radiation. Equipments which include microwave (200 MHz to 25.4 GHz) sources shall be designed to preclude crew exposure to greater than 10 mW/cm<sup>2</sup>.
- 3.9.4.2.14 Radioactive radiation. Equipments that contain radioactive materials or contain equipment that generated ionizing radiation shall be identified and approval obtained for their use.
- 3.9.4.2.15 Audio noise. The noise produced by experiment equipment shall not exceed (TBD).
- 3.9.4.2.16 Environments influences. All Labcraft equipment shall be designed so that it can withstand the launch, operational, and reentry dynamic environment and the maximum crash landing loads defined in Reference 2.2.1(c) without failures, leaking hazardous fluids, or releasing equipment, loose debris and particles which could damage other experiments and equipment, the Spacelab/Orbiter or cause injury to the crew.
- 3.9.4.2.17 Reusable hardware. Payloads and derivations of payloads (including line replaceable units and associated integrator-supplied equipment) utilized for previous missions shall be verified for:
- (a) Any maintenance and/or refurbishment affecting safety.
  - (b) Safety of reuse in view of gradual wearout of the hardware or subtle degradation in previous use.
- 3.9.4.2.18 Detailed safety requirements for levels I, II, III and IV ground operations are as follows: Labcraft operations at KSC (levels I, II, III). The Labcraft system design and operations shall conform to all the safety design and operating requirements defined in Reference 2.2.2(c) and to the requirements of FED/OSHA (public law 91-596). Other requirements are TBD.
- 3.9.4.2.19 Level IV operations. All operations that are performed at KSC must conform to K-SM-14 requirements and the Fed/OSHA requirements. All systems operations and designs performed at locations other than KSC must as a minimum conform to the requirements of the "Safety Policy and Requirements for Payloads using the National STS," and to the Fed/OSHA requirements or to the State OSHA requirements where the Level IV operations occur. Other requirements are TBD.
- 3.9.4.2.20 OSHA safety requirements. The Labcraft system shall be designed such that it strictly adheres to all the Fed/OSHA standards/law and the applicable state OSHA standards/law during all ground operations.

- 3.9.5 Parts selection. The parts approach for Labcraft Equipment will be consistent with the reliability requirements of the various equipments used. Where off-the-shelf equipment is being used that has demonstrated capability meet program requirements, that equipment will be used unchanged. In new design hardware, commercial parts may be used where practical. FMEA's and the critical item list will be reviewed on all hardware and where failure points are identified that might cause multiple equipment failures or cause loss of critical functions, improved reliability piece parts will be used.
- 3.9.6 Quality control. Hardware will be inspected to good workmanship standards. Reference 2.2.3(h) will be used as a guide in production and inspection of the hardware.

#### 4. SAMPLING, INSPECTION AND TEST PROCEDURES

(TBD)

#### 5. PREPARATION FOR DELIVERY

(TBD)

## 6. NOTES

### 6.1 DEFINITIONS OF TERMS

Airlock. An intermediate volume between vacuum and a pressurized volume which can be pressurized or depressurized on command.

Assembly. A combination of assembled components forming a self-contained operating unit necessary to the operation of a subsystem, such as power inverters, heat exchangers, etc.

Caution. A condition where a hazard to crew safety could develop if no remedial action is taken.

Central integration site. An assembly and checkout site, where Spacelab buildup, experiment installation and post-installation checkout activities are performed.

Checkout. A sequence of activities and processes to examine the performance of a unit, subsystem, or system under various operating conditions.

Component. An article composed of a group of assembled parts which is a self-contained element of a complete operating unit and performs a function necessary to the operation of the assembly; such as meters, valves, actuators, etc.

Docking module. A removable module that can be installed in the forward end of the payload bay to provide shirt sleeve transfer to another Orbiter or space vehicle equipped with a compatible docking device.

Emergency. A condition where an immediate hazard exists threatening crew safety.

Engineering model. A full-size structural model, dimensionally correct (including interfaces), with subsystems functionally identical to the flight unit (but not necessarily fully qualified), and comprising all system constituents necessary to assemble any flight configuration. The model will represent the flight unit in all respects as it is known at the time of Critical Design Review (CDR) and its configuration will be maintained to reflect the flight configuration.

EVA. Crewman activities conducted outside the spacecraft pressure hull or within the payload bay when the payload bay doors are open, during flight operations.

Experiment. The performance of the scientific or applications investigation undertaken to discover unknown phenomena, establish the basis of known laws, or to evaluate applications processes and/or equipment.

Fail-safe. The ability to sustain a failure and retain the capability of terminating a flight without injury to personnel or vital spacecraft systems.

Flight success. The proper functioning of Spacelab, its subsystems, and the experiment support equipment provided to the users, but not of the experiments themselves.

Labcraft equipment (LC/E). That portion of the payload which supports scientific instruments and completes the interface between the payload and Orbiter/Spacelab and between the payload and the crew.

Flight unit. A unit that comprises all system constituents necessary to assembly any flight configuration having met all qualification and acceptance test requirements.

Hatch. Door for personnel ingress and egress.

Igloo. A pressurized and temperature controlled compartment. For housing of Spacelab subsystem equipment on pallet only missions.

Instrument. See Scientific Instrument.

Instrument installation. The physical installation of instruments on Spacelab experiment racks or rack sets, sections, or pallet sections.

Instrument integration. Those Spacelab program activities that are performed to assure physical and functional compatibility of instruments with the Spacelab, with other instruments, with GSE, with the test, operational, and storage environments, and with ground and flight personnel.

Integration. A combination of activities and processes to assembly components, subsystems, and system elements into a desired configuration and to verify compatibility between the constituents of the assembly.

Integration levels. The major steps (integration levels) in ground operational processing of Spacelab, following refurbishment, and of its experiment payload are:

- |           |  |
|-----------|--|
| Level I   | Integration and checkout of the Spacelab and its payloads with the Shuttle Orbiter, including the necessary preinstallation testing with simulated interfaces.   |
| Level II  | Integration and checkout of the combined payload equipment and Spacelab elements (e.g., racks, racks sets, and pallet segments) with the flight subsystem support elements (i.e., basic module, igloo) and extension modules, when applicable. |
| Level III | Combination, integration and checkout of Spacelab elements (e.g., racks, rack sets, and pallet segments) with payload equipment already installed, and of payload and Spacelab software.   |

Interface. The physical and operational common boundary between two constituents of a system. The major Labcraft payload interfaces are:

Labcraft/Spacelab interface

Labcraft/ground support interfaces

Labcraft/subsystem interfaces

Labcraft/segment interfaces.

Labcraft support equipment. Labcraft support equipment is a category of flight equipment required to achieve Labcraft mission objectives. It includes subsatellites (ESP's), releases, masts, and other hardware required to assemble, mount, control, and generally support the Labcraft instruments.

Launch site. The Kennedy Space Center (KSC) or Western Test Range (WTR). Current Spacelab operational processing studies have been based upon utilization of KSC as the prime launch site with WTR being considered for later activation.

Line replaceable unit (LRU). The assembly level at which replacement on Spacelab takes place during maintenance operations.

Maintenance. The actions taken to retain an item in a specified condition by systematic inspection and servicing; and the actions taken to restore an item to such condition, including fault detection, repair, item replacement, and verification.

Mission. The planning and execution of an experiment program to achieve a particular science, applications, or technology objective; it may involve one or more flights.

Mockup. A full-scale replica, dimensionally correct, with all equipment simulated in actual size, to be used for internal arrangement studies. A mockup shall be capable of transportation via air, land or sea.

Module. A pressurized manned laboratory suitable for conducting science, applications and technology activities on Space Shuttle Sortie Sortie missions. A section of the module will be devoted primarily to subsystem support for experiments mounted in the module or on the pallet, (basic module) and one or more additional sections may be devoted primarily to housing experiment apparatus and activities (extension module).

Multi-mission support equipment (MMSE). Equipment available from Orbiter/Spacelab inventory which can be used by several Spacelab payloads.

Orbital maneuvering system (OMS). An auxiliary tankage and pressurization system that can be installed in the Orbiter payload bay in incremental kits to increase the on-orbit maneuvering capability of the Shuttle Orbiter.

Orbiter turnaround. The time between landing and launch of the same Orbiter.

Pallet. An external unpressurized platform for mounting telescopes, antennas and other instruments and equipment requiring direct space exposure for conducting science and applications activities on Space Shuttle Sortie missions, the pallet may be composed of segments.

Pallet element mode. A flight configuration in which one or more pallet segments, carrying self-contained experiments, may be mounted at any suitable location within the Orbiter payload bay, requiring no other Orbiter support. Pallet elements may be flown taking advantage of available volume and weight of any Shuttle flight.

Pallet-only-mode. A flight mode utilizing only the pallet, with subsystem support from the Orbiter and/or from igloo mounted subsystem equipment. Pallet only flights shall have the same Orbiter resources interfaces as the module/pallet flights.

Part. A piece of equipment that cannot be further disassembled without destroying its usefulness.

Principal Investigator. A scientist responsible for establishing scientific mission objectives and instrument operation, and for scientific data analysis.

Prototype. A Spacelab unit, built to flight configuration definition, that differs from the flight unit only with respect to its testing history.

Qualification. Determination that an article or material is capable of meeting all design and performance requirements established for the item. An item can be qualified by test, by analysis, or by similarity to a qualified item.

Racks. Removable/reusable assemblies that provide structural mounting and connects to supporting subsystems (power, thermal control, data management, etc.) for experiment equipment which is housed in the pressurized module.

Remote manipulator system (RMS). A manipulator system providing one manipulator arm stowed inside the payload bay but outside the Spacelab dynamic envelope. A second arm can be provided, if required, but will be weight chargeable to the Orbiter payload.

Residual-hazard. Hazard for which safety or warning devices and/or special means or procedures have not been developed or provided for counteracting the hazard.



Safe-life. A design philosophy under which failure or abort will not occur because of undetected flaws or damage during the service life of the vehicle; also, the period of time for which the integrity of the system can be ensured in the expected operating environments.

Scientific instrument. A unit or assembly of hardware designed specifically for the generation of signal or stimuli or for the acquisition of scientific data. Also referred to as an instrument.

Shirt sleeve environment. An atmospheric environment habitable for men without protective pressure suits.

Shuttle interface equipment. Equipment facilitating the interfacing of Spacelab with the Shuttle Orbiter.

Shuttle Orbiter. The orbital flight vehicle of the Space Shuttle transportation system.

Shuttle Orbiter payload. Anything transported during the mission by the Shuttle Orbiter vehicle and not weight chargeable to the basic Orbiter. For Spacelab missions, the Shuttle Orbiter payload consists of the Spacelab with the Spacelab payload, crew, consumables, and all Orbiter payload chargeable support equipment, whether installed in the payload bay or elsewhere in the Orbiter.

Shuttle Orbiter payload bay. A cylindrically shaped compartment inside the Orbiter of 18.288 m (60 feet) length and 4.752 m (15 feet) diameter for accommodation of payloads.

Sortie flight. A short duration (nominally 7 days extendable up to 30 days) flight, which is conducted in low-earth orbit using the Shuttle Orbiter and equipment attached to it for experiments, observations and other space activities.

Spacelab. A laboratory designed for space operations, composed of modules and pallets suitable for accommodating instrumentation for conducting research and application activities on Shuttle Sortie flights. On a given flight, the Spacelab configuration can be comprised of a module only, a pallet only, or a combination of a module and a pallet.

Spacelab payload. All experiments, experiment support equipment, and experiment required consumables, carried by Spacelab or elsewhere in the Orbiter, associated with Spacelab missions.

Software. All non-hardware items necessary to operate a computerized system, such as programs, instructions, subroutines, etc.

Subsystem. A collection of hardware capable of performing a major system function or related functions.

Testing. A sequence of activities and processes to determine, under real or simulated conditions, the capabilities, limitations, reactions, effectiveness, reliability or suitability of materials, parts, components, subsystems and systems.

User. The organization or individuals having responsibility for payloads installed in a Spacelab.

Warning. A condition where a hazard to crew safety will develop unless immediate remedial actions are taken.